INTRODUCTION

Sometimes whole or a part of animal population moves across the face of the earth, even undertaking journeys of immense length and duration. Such movements when regular and cyclic and are not haphazard, are termed migration. The cycles are related to a natural rhythm which controls many aspects of migratory behaviour. However, migration in its true sense is unique characteristic of only a few groups of animals (some butterflies, dragonflies and locusts, fishes, reptiles, birds and mammals). The fascinating phenomenon of animal migration had attracted great minds of all ages, from Aristotle in the 5th century B.C. through naturalists of fame including Darwin in the 19th century.

The migratory birds, the most spectacular migrants, invigoured a number of scientists to inquire about when, why, and how, regarding migration. The mechanism that initiates and maintains the migratory activities in birds have been subject of numerous investigations and hypotheses. Endocrine system has been considered as a prima facie causative factor of such mechanism. The pioneer experiments suggesting involvement of endocrine system were those of Rowan (1926, 1932, 1946) who proposed that the gonads which developed under the influence of increased day length are a part of the

physiological mechanisms that induce vernal migratory behaviour in Junco hymelis. While the experiments conducted by several other workers (Putzig, 1939; Lofts and Marshall, 1960, 1961; Dolnik, 1961; Morton and Mewaldt, 1962 and King and Farner, 1963) indicated that migration or migratory behaviour can occur in castrates among several passerine species. This raised objection to any general hypothesis that involves gonads as an integral part of a mechanism that initiates migratory behaviour. The photoperiod on the other hand is considered as an important factor; functioning as primary annual "timer" in the initiation of gonadal growth, fat deposition and vernal migration (King et al., 1965). King (1968) reported that increasing vernal photoperiod activates physiological sequence that induces premigratory fattening. Farner (1964), Dolnik and Blyumental (1967) suggested that the increased photoperiod acts at least in part through hypothalamo-hypophysial neurosecretory system. Morton et al. (1973) reported that the premigratory fattening is the direct result of hyperphagia induced by lengthened photoperiod. Wheeland et al. (1976) reported an increase in lipogenic enzymes and increased lipid synthesis in photostimulated white-throated sparrow (Zonotrichia albicollis). Kuenzel and Helms (1970) suggested that some part of the central "clock", timing and synchronizing the annual cycle,

may be located in the ventromedial hypothalamus.

Wolfson (1945) provided evidences that anterior pituitary is involved in regulation of migration. Meier and Farner (1964) reported that prolactin can induce a rapid fat deposition in the White-crowned Sparrow (Zonotrichia leucophrys gambelii). There are also evidences suggesting possible relationship between thyroid gland and migration (Wagner, 1930; Merkel, 1937, 1938, 1940, 1958; Schildmacher and Rautenberg, 1952; Pilo and George, 1970).

George and his colleagues (George, 1974), in this laboratory, studied certain aspects of adaptive physiological changes in Rosy Pastor and Wagtail, mainly in the hypothalamo-hypophysial neurosecretory system; other endocrine glands and some aspects of metabolism of the liver and muscles.

Thus, the migration is the result of well synchronized and integrated action of photoperiod, hyperphagia, endocrine system, changes in intermediary metabolism, fat deposition and migratory behaviour; in other words, the adaptations of the migratory birds to migrate are apparently achieved as a result of coordination of biological integration at various levels. In this sense several physiological and histochemical changes in the organs and their cellular elements constitute the necessary basis for the adaptive reactions in the migratory birds.

Though, much is known about some of these adaptive physiological and biochemical changes, several others remain yet to be explained. The present work is an attempt to widen the vistas of knowledge regarding certain aspects of adaptive changes in the migratory birds with emphasis on premigratory hyperlipogenesis. Since 1822, as noted by Naumann (Dorst, 1961), fat deposition has been closely associated with the migration. Within the period of last five decades, number of reports have appeared suggesting that an increase in weight of migratory birds due to fat deposition is characteristic of the premigratory period. Dolnik and Blyumental (1967) suggested that hyperphagia results in supplying the organism with abundant energy source and changes the equilibria of intermediary metabolism that intensifies fat metabolism. However, scant progress has been made in the understanding of the mechanisms involved in building up reserve energy source (fat) from the metabolites available through the diet.

The development of hyperphagia that brings about increased food intake would naturally result in burdening alimentary canal with increased activities for digestion and absorption. Hence certain adaptive physiological changes occuring in the alimentary canal were studied in the present investigation.

Liver, is the major site for lipogenesis in birds

and this organ is the center of major metabolic pathways linked to interconversion of metabolites. So it was deemed worthwhile to study certain aspects of physiological activities in liver, which forms the major part of this thesis.

The present investigation was carried out on two species of migratory birds viz., Rosy Pastor (Sturnus roseus) and white Wagtail (Motacilla alba). Rosy Pastors arrive in Baroda, India in July/August and leave for their breeding grounds (Asia Minor and USSR) in April/May. The Wagtails, come for wintering in India in September/October and leave for their breeding ground in March/April. July to October were arbitrarily designated as the postmigratory period while March and April as the premigratory one.

Rosy Pastors, during their postmigratory period feed on insects and grains while during the premigratory period feed mainly on carbohydrate rich fruits. Wagtails, all throughout feed on ants, termites, grubs and small worms and are seen frequenting the marshy places, river and stream banks, irrigated fields and gardens.

Hyperphagia, i.e. manifold increase in the uptake of food can be taken as prime factor responsible for hyperlipogenesis. In light of this fact in the present study

greater attention has been paid to the digestive system and adaptive changes occuring therein.

Acid and alkaline phosphatases, the enzymes catalysing the hydrolysis of phosphate esters, are reported to be present in variety of tissues and cells. Different functions are ascribed to these enzymes according to their distribution. The alkaline phosphatase is commonly associated with the absorptive and secretory activities of different organs. Acid phosphatases are usually lysosomal enzymes and are associated with lytic activity of the cells. But several workers have reported that both these enzymes play important roles in protein synthesis also. Because of their ubiquitous and nonspecific nature the phosphatases could readily participate in many of the adaptive changes taking place in the alimentary canal. To understand physiological adaptations of the digestive system in the migratory birds, histochemical and quantitative studies on these phosphatases in different parts of the alimentary canal were carried out (Chapter 1 and 2). The quantitative estimations of acid and alkaline phosphatases in liver and kidney of both Rosy Pastor and Wagtail were also made to gather information regarding changes in the hepatic and renal functions during their premigratory period (Chapter 3).

During hyperlipogenesis in migratory birds, the

liver shares the major responsibility of fatty acid synthesis, while contribution of adipose tissue to lipogenesis is very poor nevertheless it acts as a storage site. Since the knowledge regarding machinery of hyperlipogenesis in the migratory birds is poor, a study on certain aspects of lipogenesis in Rosy Pastor and Wagtail was also carried out. It is well established that fatty acid synthesis requires cytoplasmic reduced pyridine nucleotides. Glucose-6-phosphate dehydrogenase and "Malic" enzyme are two crucial enzymes in the biochemical reactions generating reduced pyridine nucleotides. Thus, the changes in the degree of the activities of these two enzymes could be considered as an index of the rate of lipogenesis and hence a quantitative study of G-6-PDH and "Malic" enzyme in the liver and adipose tissue of Rosy Pastor and Wagtail was carried out (Chapter 4).

Besides such preferential activities of metabolic pathways, liver also performs a large number of other functions at higher rate during premigratory preparations and the energy required for such activities is obtained by oxidation of various metabolites. Therefore, a study on the activities of Succinic dehydrogenase and Adenosine triphosphatase was carried out to probe into the energy yielding mechanisms (Chapter 5).

It is well known that total lipid content in the

liver of migratory birds increases during the premigratory period. Same is the case with the Rosy Pastor and Wagtail. Liver lipid of both the birds was analysed to provide data regarding the type of lipid accumulated and an attempt is made to explain the mechanism of accumulation of lipid in the liver of these migratory birds (Chapter 6).

As far as the metabolic activities are concerned the liver is the most active organ. To facilitate such hyperfunctions during the premigratory period, it is assumed that hepatic cells may show hypertrophy and/or hyperplasia. Liver histology and quantitative estimations of nucleic acids in the liver of Rosy Pastor and Wagtail were carried out to ascertain the validity of this assumption (Chapter 7).

Arginase is one of the enzymes concerned with the metabolism of proteins. This enzyme has been found to be present in the liver and kidney of several species of birds but its functional significance in birds is not clear. A study on arginase activity in the liver and kidney of Rosy Pastor and Wagtail was carried out in order to find its possible functional significance during hyperphagia as well as its relationship with the diet consumed by the birds (Chapter 8).

As mentioned earlier, the thyroid gland could have an integral function in the preparation and initiation of

migration. Present work on the thyroidectomized Rosy Pastors was carried out with a view to find out if this gland has any role to play in the premigratory preparations manifested in the Rosy Pastor (Chapter 9). For want of birds similar studies on Wagtail were not conducted. However, it is planned as and when Wagtails can be captured.

CHAPTER 1

ADAPTIVE CHANGES IN THE ACTIVITIES OF ACID AND ALKALINE PHOSPHATASES IN THE ALIMENTARY CANAL OF MIGRATORY BIRDS, WAGTAIL (*MOTACILLA ALBA*) AND ROSY PASTOR (*STURNUS ROSEUS*)

Importance of premigratory fattening in the migratory birds has been well established by many scientists (Odum and Perkinson, 1951; Wolfson, 1954; McGreal and Farner, 1956; George and Berger, 1966; John and George, 1966; Pilo, 1967). Of the various physiological factors that are known to influence the premigratory fat deposition in migratory birds, hyperphagia has been considered to be the foremost (King and Farner, 1956; Merkel, 1958; Odum, 1960; Dolnik *et al.*, 1963a,b). Besides hyperphagia, a shift from a mixed diet (grains and insects) to a carbohydrate rich diet (fruits), as seen in the migratory starling *Sturnus roseus* (Pilo, 1967), also helps in establishing the premigratory obesity. The manifestation of hyperphagia and perhaps also the change in the food preference, being influenced by hormonal interplay, may bring about several other physiological changes in the body of the migratory birds so as to prepare themselves for the sojourn. The process of hyperlipogenesis is a metabolic adaptation

induced in various tissues by hormones through their action on enzymes concerned. The enzymatic adaptations are some of the prerequisites for the increased uptake of metabolites and fatty acid synthesis. Such adaptations are mainly seen in the alimentary canal, liver and adipose tissue which are related with absorption, interconversion of the metabolites or synthesis as well as storage of fat. Hyperlipogenesis during premigratory period in the migratory birds has attracted much attention, however, the data on the adaptive changes in the alimentary canal of the migratory birds with reference to hyperphagia and hyperlipogenesis is meagre. The hyperphagia would naturally demand enhanced digestive and absorptive activities of the alimentary canal.

An association of phosphatases with the functional aspects of alimentary canal has been suggested by several workers. Acid phosphatase has been reported to be localized in the golgi zone of epithelial cells of the intestinal villi of rat and is associated with mucin formation (Ogawa et al., 1962). The enzyme is usually considered to be associated with "lysosome" concept (Duve, 1959; Novikoff, 1961) which has been substantiated by several workers (Behnke, 1963; Barka, 1964; Hsu and Tappel, 1964) who have suggested that the acid phosphatase is localized in lysosomes and helps in intracellular digestion of phagocytosed exogenous material.

A relationship between the acid phosphatase and protein synthesis has also been claimed by several workers (Eränkö, 1951; Vorbrodt, 1958; Singer, 1964; Kokko, 1965 and Pearse, 1968).

Evidences showing the role of alkaline phosphatase in the secretory and absorptive activities of cells have been given by Baradi and Bourne (1959), Berkaloff (1959), Byczkowska-smyk and Bernhard (1960) and Mölbert et al. (1960). Moreover, a role of alkaline phosphatase in protein synthesis has also been suggested by Moog (1950), Venugopalan (1961) and Sethi et al. (1969). It seems possible that both the phosphatases in one respect or other are involved in protein synthesis but the activity of one or the other in a particular cell depends upon cellular environment, especially its pH.

Since alkaline and acid phosphatases are known to play significant roles in secretion of digestive enzymes and in absorption of digested food, it was thought desirable to study these two phosphatases histochemically and quantitatively in various parts of the alimentary canal of two migratory birds viz., Rosy Pastor (Sturnus roseus) and Wagtail (Motacilla alba) during their post and premigratory periods to elucidate adaptive changes, if any, occuring in their alimentary canal.

MATERIALS AND METHODS

Migratory Rosy Pastors (Sturnus roseus) and Wagtails (Motacilla alba) arrive in Baroda (India) by August/September and September/October respectively and they leave for their breeding grounds by March/April. Wagtails feed on ants, termites, grubs, small worms and are seen frequenting marshy places, river and stream banks, irrigated fields and gardens, searching for their prey. Rosy Pastors, during their post-migratory period feed on insects and grains while during premigratory period they mainly feed on carbohydrate rich fruits (fruits of Pithacolobium dulce).

Wagtails and Rosy Pastors, during their premigratory and postmigratory periods, were shot with air rifle within the University Campus and were brought to the laboratory immediately. Different parts of their alimentary canal (viz., proventriculus, gizzard and small intestine) were quickly removed, made free of their contents and processed for histochemical and quantitive studies of acid and alkaline phosphatases.

For histochemical studies, tissues obtained from recently shot birds were fixed on microtome chuck mounted in a cryostat maintained at -20°C. 12 to 15 μ thick sections were cut and were processed for histochemical demonstration

of the localization of acid and alkaline phosphatases, employing the technique described by Burstone (1962). Naphthol AS-MX phosphoric acid and Naphthol AS-BI phosphoric acid (disodium salt) were used as substrates for alkaline and acid phosphatase respectively; while the diazonium salt used was Fast Blue B (Sigma Chemical Co., U.S.A.). Controls were run to check the authenticity of the histochemically obtained enzyme reactivity.

Tissue homogenates were prepared in cold distilled water and were used for quantitative estimations of acid and alkaline phosphatases employing the method described in Sigma Technical Bulletine No. 104 using p-Nitrophenyl phosphate as the substrate. Protein concentrations in the tissue homogenates were determined by the method of Lowry et al. (1951) using phenol reagent (Folin-Ciocalteu's). Enzyme activities are expressed as μ mole p-Nitrophenol released/ mg protein/ 30 minutes.

RESULTS

Histochemical observations

ACID PHOSPHATASE:

Proventriculus and Gizzard: During the postmigratory

period; in Wagtail and Rosy Pastor, the acid phosphatase reactivity was detected in the form of fine granules in the tubules and glands of both the proventriculus (Figs. 1 and 5; 3 and 7) and gizzard (Figs. 9 and 11) which increased during the premigratory period (Figs. 2,4,6,8,10,12). Besides, during the postmigratory period, the ducts that arise from glands and open in between the tubules in gizzard were negative to enzyme reactivity but revealed acid phosphatase activity during the premigratory period.

Small intestine: In both the birds, during postmigratory period the acid phosphatase reactivity was localized in the following parts of their intestine: Brush border, epithelial cells of the villi and intestinal glands (Figs. 13, 15 and 17, 19). Without any change in its localization the enzyme reactivity increased in these intestinal regions of both the migratory birds during premigratory period (Figs. 14, 16 and 18, 20).

ALKALINE PHOSPHATASE:

Proventriculus and Gizzard: In both the birds during postmigratory period, the tubules of proventriculus (Figs. 21 and 25) and gizzard (Figs. 29, 31) were only slightly enzyme positive, while their glands did not show any reactivity for the enzyme (Figs. 23, 27). But, during the premigratory period

EXPLANATIONS FOR FIGURES

Figs. 1-20. Photomicrographs of sections of different parts of the alimentary canal showing acid phosphatase activity.

Fig. 1. Mucosal tubules of Wagtail proventriculus (POM). 125X.

Fig. 2. Mucosal tubules of Wagtail proventriculus (PM). 125X.

Fig. 3. Glands of Wagtail proventriculus (POM). 125X.

Fig. 4. Glands of Wagtail proventriculus (PM). 125X.

Fig. 5. Mucosal tubules of Rosy Pastor proventriculus (POM). 125X.

Fig. 6. Mucosal tubules of Rosy Pastor proventriculus (PM). 125X.

Fig. 7. Glands of Rosy Pastor proventriculus (POM). 65X.

Fig. 8. Glands of Rosy Pastor proventriculus (PM). 65X.

Fig. 9. Gizzard of Wagtail (POM). 125X.

Fig. 10. Gizzard of Wagtail (PM). 125X.

Fig. 11. Gizzard of Rosy Pastor (POM). 125X.

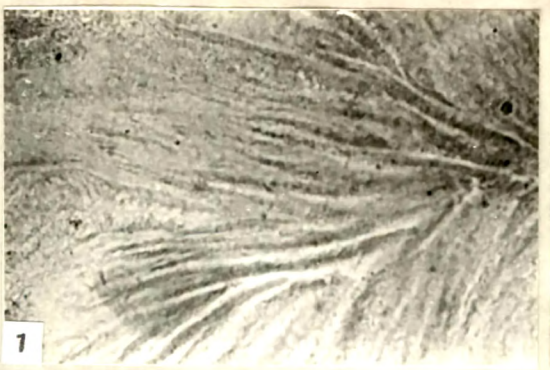
Fig. 12. Gizzard of Rosy Pastor (PM). 125X.

Fig. 13. Intestinal villi of Wagtail (POM). 125X.

Fig. 14. Intestinal villi of Wagtail (PM). 125X.

Fig. 15. Intestinal glands of Wagtail (POM). 125X.

Fig. 16. Intestinal glands of Wagtail (PM). 125X.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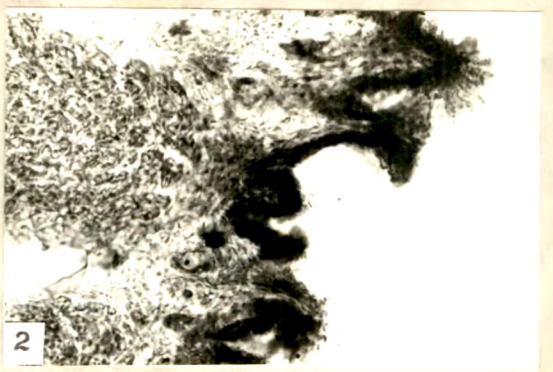
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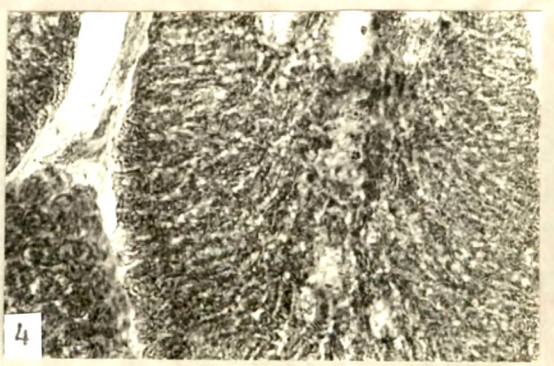
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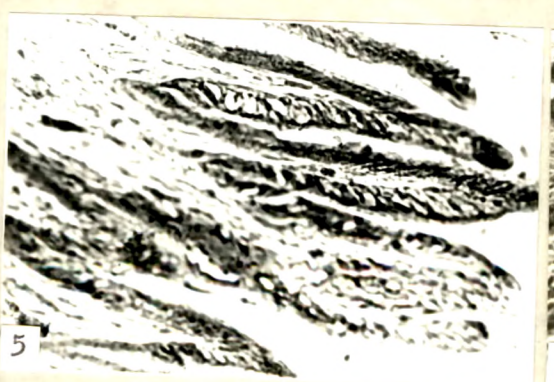
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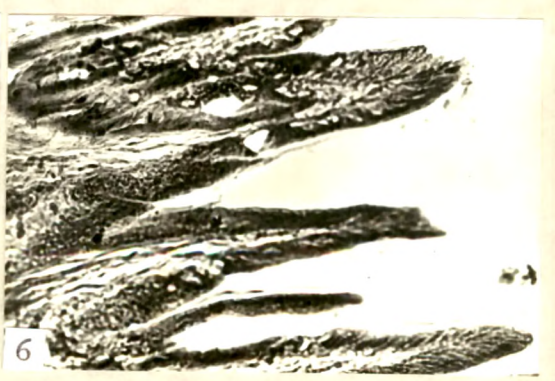
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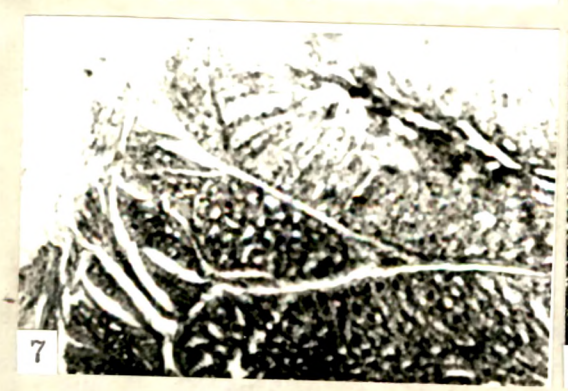
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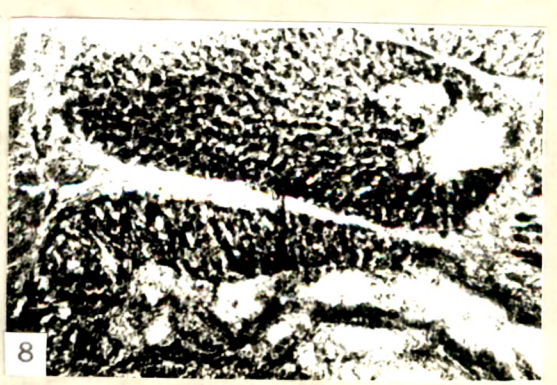
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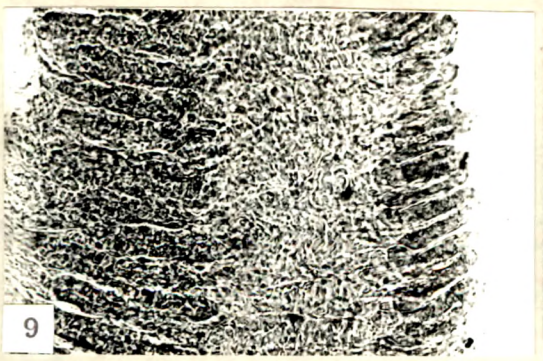
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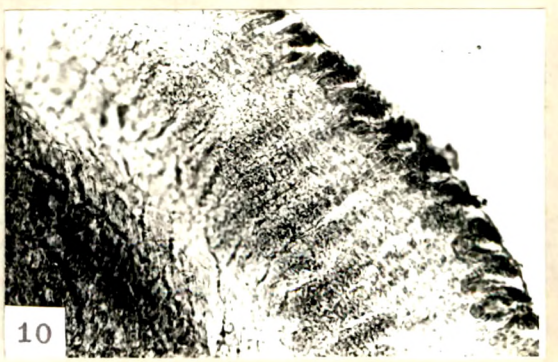
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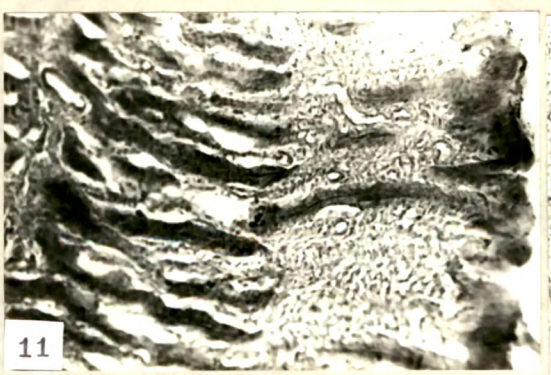
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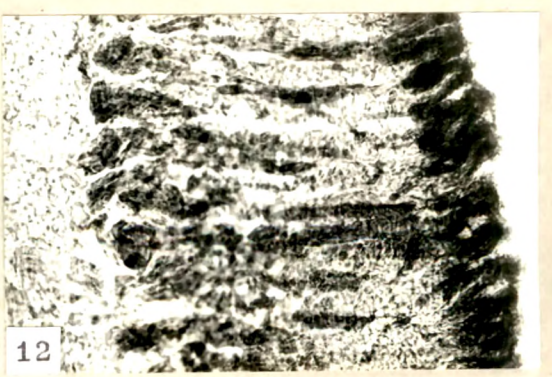
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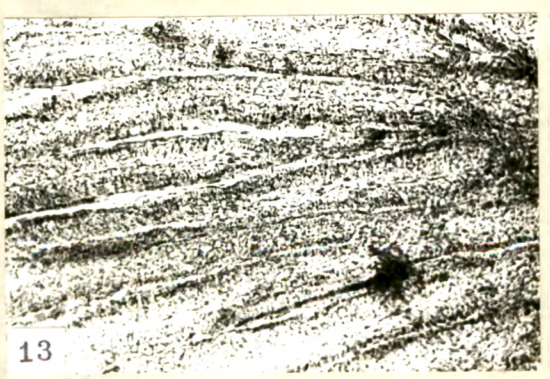
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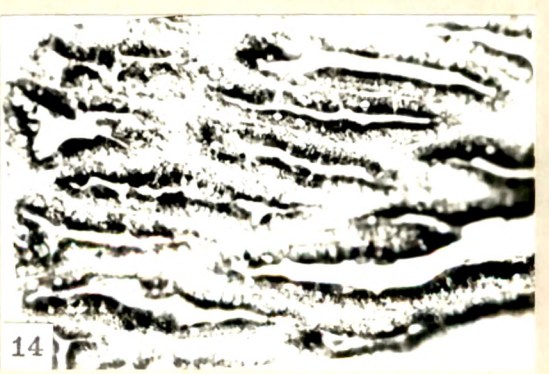
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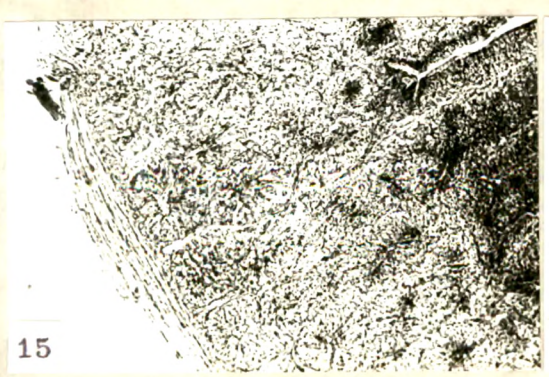
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Fig. 17. Intestinal villi of Rosy Pastor (POM). 125X.

Fig. 18. Intestinal villi of Rosy Pastor (PM). 125X.

Fig. 19. Intestinal glands of Rosy Pastor (POM). 125X.

Fig. 20. Intestinal glands of Rosy Pastor (PM). 125X.

Figs. 21-40. Photomicrographs of sections of different parts of the alimentary canal showing alkaline phosphatase activity.

Fig. 21. Mucosal tubules of Wagtail proventriculus (POM). 125X.

Fig. 22. Mucosal tubules of Wagtail proventriculus (PM). 125X.

Fig. 23. Glands of Wagtail proventriculus (POM). 125X.

Fig. 24. Glands of Wagtail proventriculus (PM). 125X.

Fig. 25. Mucosal tubules of Rosy Pastor proventriculus (POM). 125X.

Fig. 26. Mucosal tubules of Rosy Pastor proventriculus (PM). 125X.

Fig. 27. Glands of Rosy Pastor proventriculus (POM). 125X.

Fig. 28. Glands of Rosy Pastor proventriculus (PM). 125X.

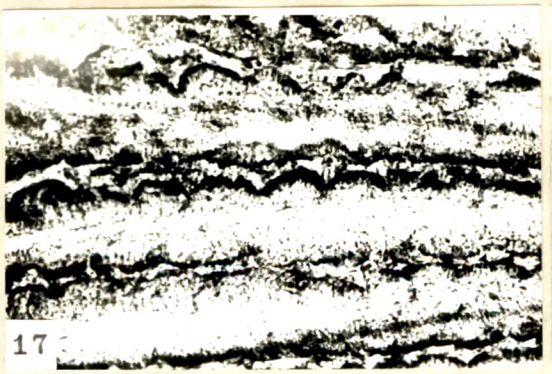
Fig. 29. Gizzard of Wagtail (POM). 125X.

Fig. 30. Gizzard of Wagtail (PM). 125X.

Fig. 31. Gizzard of Rosy Pastor (POM). 125X.

Fig. 32. Gizzard of Rosy Pastor (PM). 125X.

Fig. 33. Intestinal villi of Wagtail (POM). 125X.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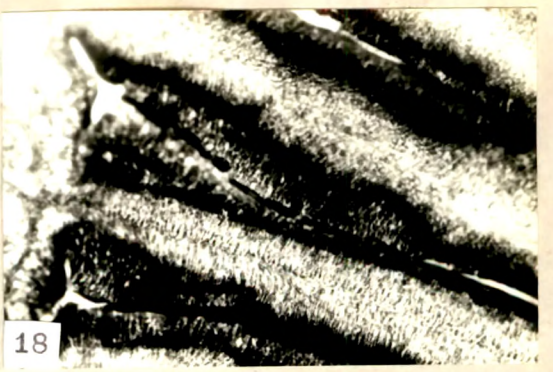
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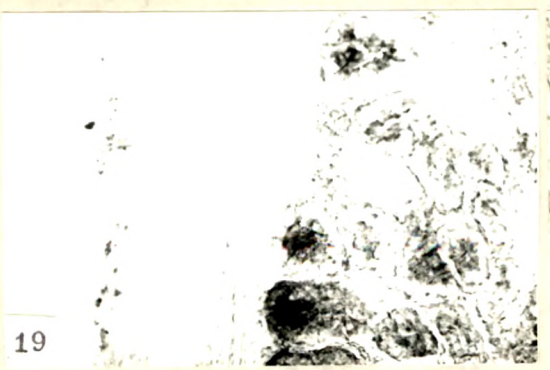
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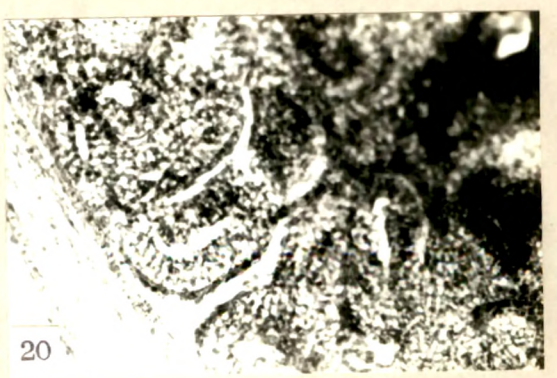
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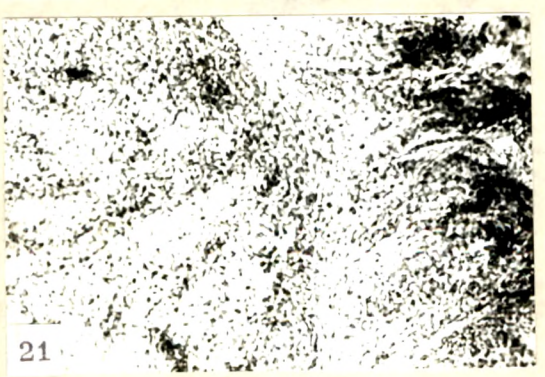
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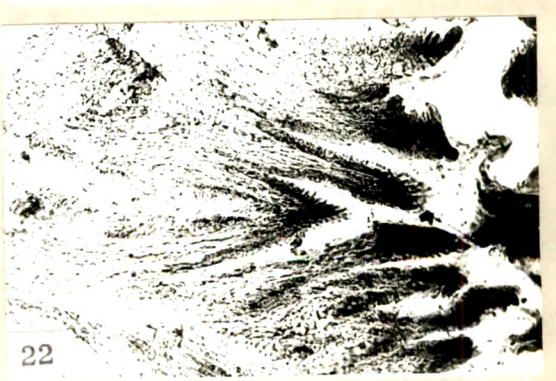
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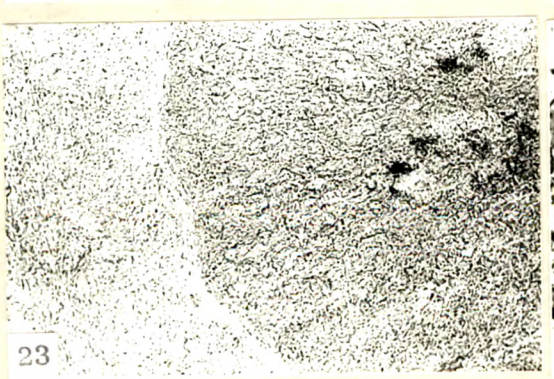
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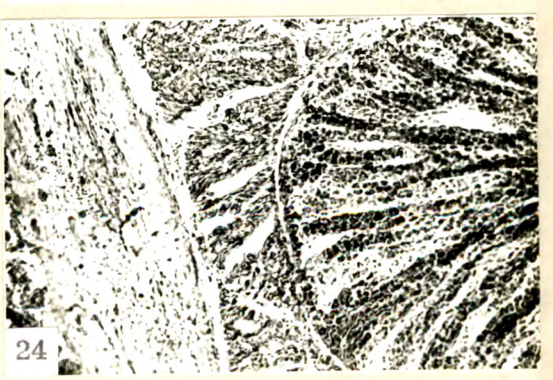
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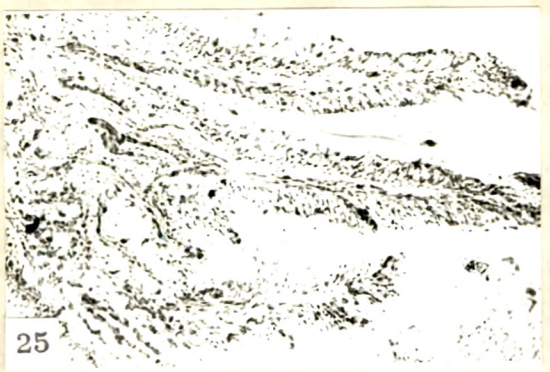
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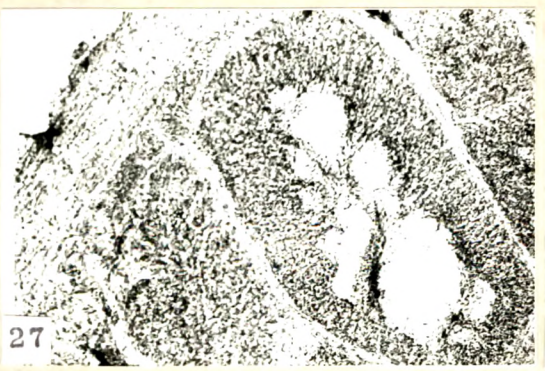
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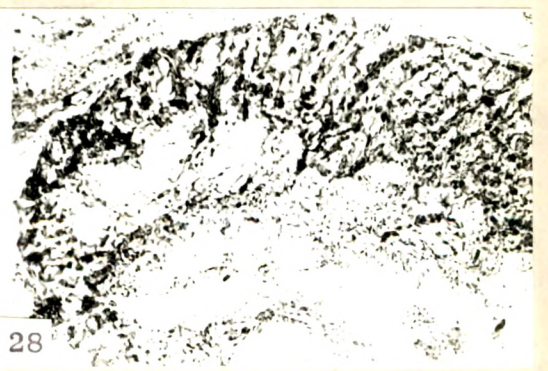
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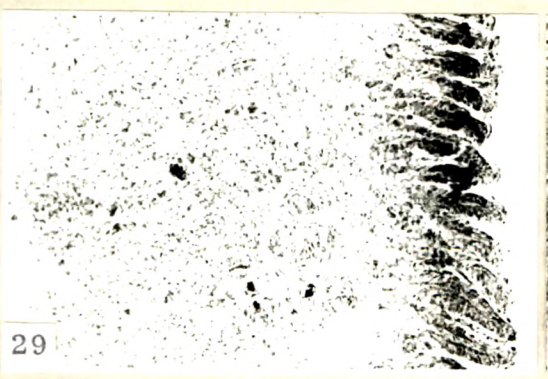
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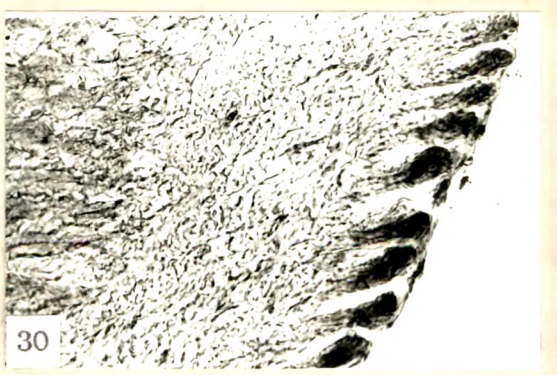
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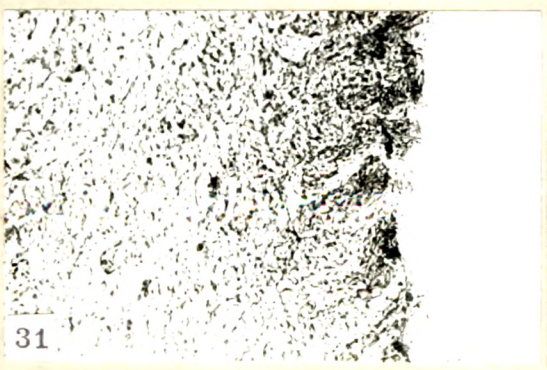
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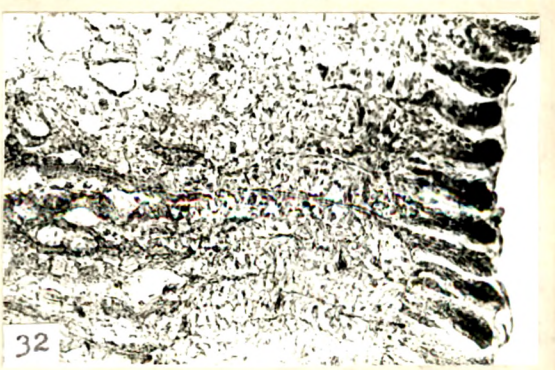
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Fig. 34. Intestinal villi of Wagtail (PM). 125X.

Fig. 35. Intestinal glands of Wagtail (POM). 125X.

Fig. 36. Intestinal glands of Wagtail (PM). 125X.

Fig. 37. Intestinal villi of Rosy Pastor (POM). 125X.

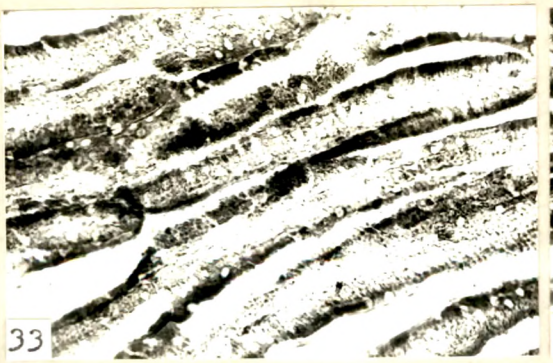
Fig. 38. Intestinal villi of Rosy Pastor (PM). 125X.

Fig. 39. Intestinal glands of Rosy Pastor (POM). 125X.

Fig. 40. Intestinal glands of Rosy Pastor (PM). 125X.

ABBREVIATIONS

POM = Postmigratory period, PM = Premigratory period.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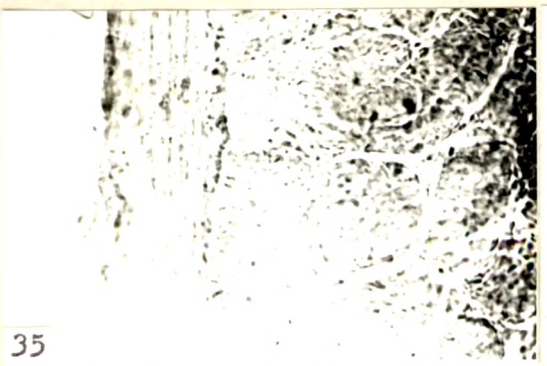
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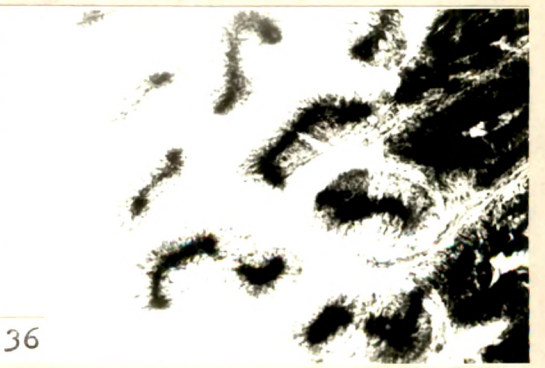
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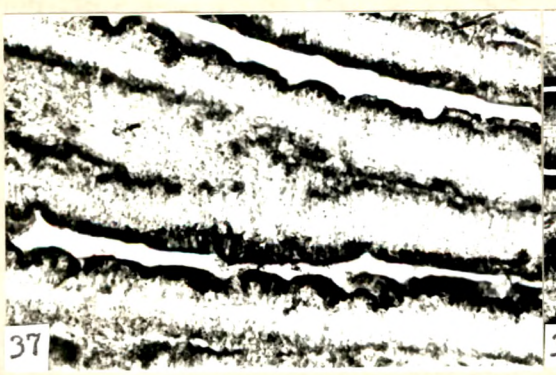
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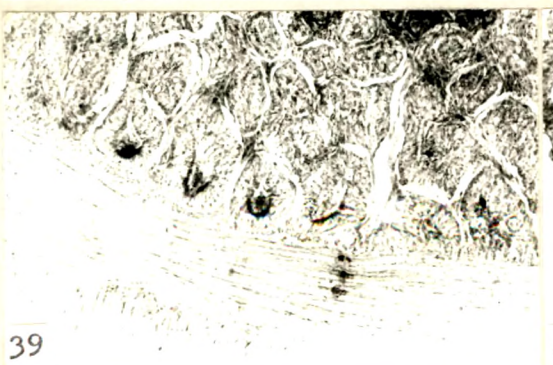
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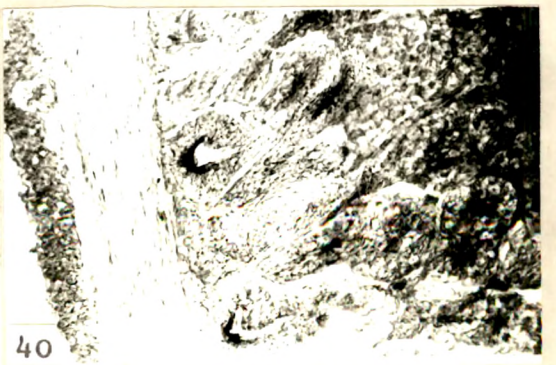
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the tubules of proventriculus (Figs. 22, 26) and gizzard (Figs. 30, 32) showed relatively increased concentration of the enzyme and the enzyme activity was slightly perceptible in the glands (Figs. 24, 28, 30 and 32).

Small intestine: An intense alkaline phosphatase activity was observed on the brush border, lamina propria and in the supranuclear zone of the absorptive cells of the villi in the intestine of both Wagtail (Fig. 33) and Rosy Pastor (Fig. 37) during their postmigratory period. During the same period, although a slight activity of the enzyme was observed in the cells of the intestinal glands of Rosy Pastor (Fig. 39), those in the Wagtail were negative to the enzyme reactivity (Fig. 35). During premigratory period, without any change in the pattern of localization, the enzyme reactivity enhanced in the above mentioned intestinal parts of both the birds (Figs. 34, 36, 38 and 40).

The alkaline phosphatase activity in the intestinal glands of Wagtail which was nil during postmigratory period appeared only during premigratory period (Fig. 36) and was much ~~more~~ higher than that observed in the intestinal glands of Rosy Pastor (Fig. 40) during the same period.

Quantitative study

Both the acid and alkaline phosphatase concentrations

TABLE 1

Acid and alkaline phosphatases activities in proventriculus of Wagtail and Rosy Pastor. Expressed as μ Mole p-Nitrophenol released/mg protein/30 minutes. Mean value ± S.D.

Month	Wagtail		Rosy Pastor	
	Acid phosphatase	Alkaline phosphatase	Acid phosphatase	Alkaline phosphatase
October	---	---	0.4766 ±0.0520	0.1074 ±0.0100
November	0.2802 ±0.0447	0.1288 ±0.0200	---	---
December	0.3283 ±0.0843	0.1030 ±0.0100	---	---
January	0.4235 ±0.0954	0.1231 ±0.0224	---	---
February	0.5421 ±0.1738	0.1882 ±0.0520	---	---
March	0.7786* ±0.0825	0.2145* ±0.0412	---	---
April	---	---	0.8095* ±0.0300	0.1337* ±0.0100
*Significant at the level	P<0.02	P<0.05	P<0.001	P<0.05

*P values refer to differences between post and premigratory periods. The Student's 't' test was used to analyze differences in means.

TABLE 2

Acid and alkaline phosphatases activities in small intestine of Wagtail and Rosy Pastor. Expressed as μ Mole p-Nitrophenol released/mg protein/30 minutes. Mean value ± S.D.

Month	Wagtail		Rosy Pastor	
	Acid phosphatase	Alkaline phosphatase	Acid phosphatase	Alkaline phosphatase
October	---	---	1.0070 ±0.0091	1.2364 ±0.0087
November	0.4879 ±0.0235	9.8450 ±0.6010	---	---
December	0.6137 ±0.1171	9.1000 ±0.7071	---	---
January	0.5590 ±0.0551	10.1450 ±0.6010	---	---
February	0.8673 ±0.0611	12.2150 ±2.8072	---	---
March	1.0600* ±0.1232	19.0720* ±1.4566	---	---
April	---	---	1.2920* ±0.0877	4.6300* ±0.5622
*Significant at the level	P<0.005	P<0.02	P<0.05	P<0.002

*P values refer to differences between post and premigratory periods. The Student's 't' test was used to analyze differences in means.

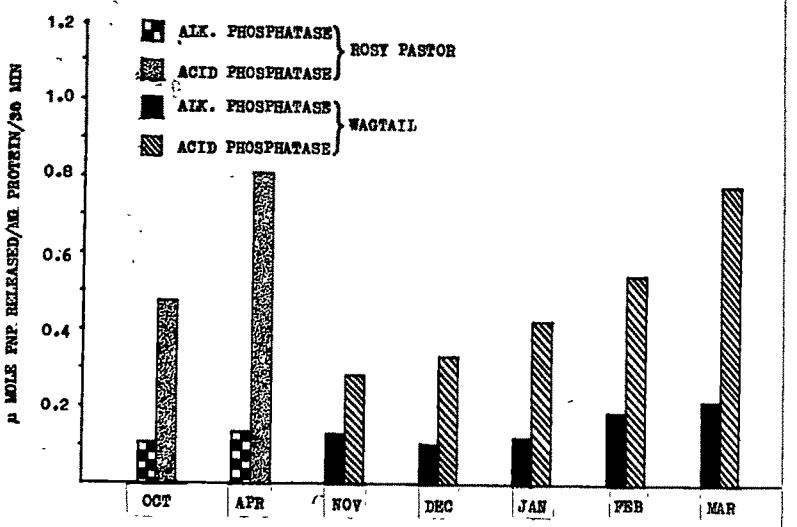

FIG. 41 LEVELS OF ALKALINE AND ACID PHOSPHATASES ACTIVITY IN THE PROVENTRICULUS OF ROSY PASTOR AND WAGTAIL. ENZYME ACTIVITY IS EXPRESSED AS µ MOLE p-NITROPHENOL (PNP) RELEASED/MG PROTEIN/30 MINUTES.

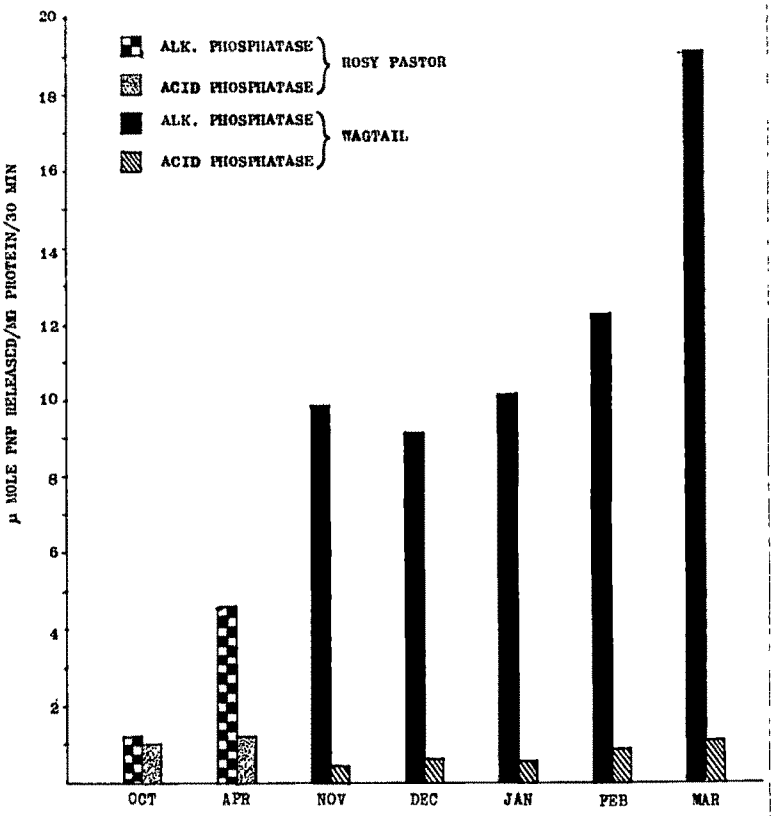

FIG. 42 LEVELS OF ALKALINE AND ACID PHOSPHATASES ACTIVITY IN THE SMALL INTESTINE OF ROSY PASTOR AND WAGTAIL. ENZYME ACTIVITY IS EXPRESSED AS μ MOLE p-NITROPHENOL (PNP) RELEASED/MG PROTEIN/30 MINUTES.

in the proventriculus of Wagtail and Rosy Pastor increased from lower values in postmigratory to higher ones in the premigratory period (Fig. 41 and Table 1). It was observed that at any stage, the activity of the acid phosphatase was relatively higher than that of the alkaline phosphatase.

Alkaline phosphatase activity in the intestine of Wagtail was more than that noticed in the intestine of Rosy Pastor (Fig. 42 and Table 2) during post as well as premigratory periods. During the premigratory period compared to the postmigratory one, the increase in the alkaline phosphatase activity in the intestine of Rosy Pastor was three fold, while that in Wagtail was only two fold. At any period the level of alkaline phosphatase in the intestine of both the birds was found to be higher than that of acid phosphatase. The acid phosphatase level in the intestine of both the birds was also found to increase during the premigratory period.

DISCUSSION

The granular localization of acid phosphatase in the glands and mucosal tubules of proventriculus of Wagtail and Rosy Pastor can be correlated with the synthesis as well as elaboration of the enzyme proteins by these parts. The enzyme activity in the tubules can be specifically related to

mucin production. The histochemical and biochemical studies on the activities of both the phosphatases in the proventriculus of the migratory birds studied, revealed that acid phosphatase activity was higher than that of alkaline phosphatase. Low alkaline phosphatase activity in the proventriculus could be explained on the basis of the fact that this part of the alimentary canal is not engaged in absorptive activity and also the pH here is always acidic. The high incidence of acid phosphatase in the glandular part of the gizzard of these two birds can be correlated with the koilin production while that in the tubules with the mucus secretion. The presence of acid phosphatase in the columnar epithelial cells of the intestinal villi and in the cells of the intestinal glands is indicative of its possible role in the active protein synthesis.

An intense alkaline phosphatase activity localized in the brush border of the intestinal villi suggests that this enzyme is concerned with active absorption of the digested food material. It has been demonstrated that alkaline phosphatase plays an important role in the absorption of fat (Dickie et al., 1955), carbohydrates and amino acids (Tuba and Dickie, 1954, 1955). The cells of the intestinal glands in the Wagtail did not exhibit any alkaline phosphatase activity during the postmigratory period but those in

Rosy Pastor, during the same period did show perceptible enzyme activity. However, during the premigratory period an intense activity of the enzyme appeared in the intestinal glands of Wagtail, while in Rosy Pastor only a slight increase in the previously existing activity of the enzyme was observed. Since the alkaline phosphatase is localized in the intestinal gland cells which are known to produce digestive enzymes, it could be surmised that the enzyme is implicated in synthesis and secretion of the digestive enzymes. The alkaline phosphatase activity in the intestine of Wagtail was always found to be higher than that in Rosy Pastor. Such high incidence of alkaline phosphatase in Wagtail could be correlated with its lipid and protein rich diet (insects).

The difference in the activities of acid and alkaline phosphatases observed in the intestine of these two migratory birds during their postmigratory as well as premigratory periods suggest ~~an~~ apparent physiological adaptations of their alimentary canal to deal with the type of food they consume. It has been reported that in birds dietary fat is absorbed by the intestinal villi and transported to the blood in the form of very low density lipoproteins (Noyan et al., 1964). These lipoproteins are synthesized by the cells of the intestinal villi. Phospholipids, a component of lipoproteins play an important role in lipoprotein

synthesis. Przeleck et al. (1962) suggested a correlation between alkaline phosphatase and the synthesis of phospholipids. In this context, the higher value of alkaline phosphatase observed in the intestine of Wagtail compared to that in Rosy Pastor could be an adaptive feature meant for dealing with relatively more lipid rich diet. Koyama and Ono (1976) have shown that short chain fatty acids induce alkaline phosphatase activity in cultured mammalian cells. Thus they have reported that there exists a relationship between short chain fatty acids and alkaline phosphatase activity in the cellular environ. In light of these facts it is likely that such a relationship also exists in the intestinal glands and mucosal cells in Wagtail which is known to feed on lipid rich diet. It is pertinent to note that experimentally it has been shown that two isoenzymes of alkaline phosphatase exist in the intestine of Wagtail (Chapter 2). The lamina propria in the intestinal villi of Wagtail presented the reactivity for Zn^{++} sensitive (liver type) alkaline phosphatase which is known to be involved in lipid absorption. Rufo et al. (1973) have also reported the involvement of liver type of isoenzyme of alkaline phosphatase in absorption of fat in the intestine of rat.

In general, the increased levels of both the phosphatases in different parts of the gut of both the

migratory birds during the premigratory period can be considered to be a response to hyperphagia. Influence of several hormones on the alkaline phosphatase activity in the duodenum and intestine have been reported by Moog (1953, 1961, 1965). It is quite likely that the hormones which influence the activity of the alkaline phosphatase may be directly or indirectly influencing hyperphagia. Tanabe and Wilcox (1961) in their study on endocrine control of serum alkaline phosphatase in chicken have reported that the administration of thyroxine increased the level of the enzyme in serum and suggested that it reflects the activity of the enzymes in other tissues viz., intestine, liver and bones. They further suggested that administration of thyroxine possibly increases the phosphatase in other tissues of the body which is responsible for the increase in the serum alkaline phosphatase level. During the premigratory period increased activity of thyroid gland has been reported in Wagtail (John and George, 1967a) and in Rosy Pastor (Pilo and George, 1970). The period of increased alkaline phosphatase activity reported herein corresponds well with the reported increase in thyroid gland activity in these birds. From these facts and the findings of the present study, it could be surmised that the increased alkaline phosphatase activity in the intestine of both the migratory birds may be

due to increased levels of thyroxine during the premigratory period.

It is known that the hypothalamo-hypophysial systems of the migratory birds are activated during the premigratory period (George and Naik, 1965, in Rosy Pastor; John and George, 1967b, in Wagtails) probably due to the changes in the environment (photoperiod and temperature). So induced activities of hypothalamo-hypophysial system, through the agency of hormones such as thyroxine, induce the hyperphagia in these migratory birds during premigratory period. Presently reported increase in the activities of phosphatases in alimentary canal clearly indicates the increased rate of food intake, digestion and absorption during the premigratory period. Such increase in the activities of gut would result in providing large amount of metabolites that could be stored in the form of fat.